MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1 2022/2023 (TERM ID 2210)

EEE3106 – PROCESSING AND FABRICATION TECHNOLOGY

(EE)

13 FEBRUARY 2023
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to the APPENDIX section on pages 6 and 7 for a list of physical constants, formulas, and the error function table.

Question 1

(a) Czochralski (Cz) is a mainstream method of growing single crystal semiconductor substrate materials for manufacturing of a wide range of microelectronic devices. Describe the advantages and disadvantages of the Cz method. [7 marks]

(b) The bulky silicon (Si) boule will be processed further into thin wafer form. Describe those processing steps involved in between. [9 marks]

(c) In a Cz process, a Si boule is pulled from the melt of polycrystalline Si and phosphorous (P) dopants. At the end of the process, the Si wafer sliced from the top of the boule has a P concentration of 5×10^{17} cm^{-3}. The segregation coefficient (k) for the P is given as 0.35. Determine the doping concentration of the Si wafer taken from the position corresponding to 60 % of the initial charge solidified. [4 marks]

Continued .....

Question 2

(a) Lithography printing is the most important step in the microelectronic device patterning processes. Describe the advantages and disadvantages for the *Contact* printing, *Proximity* printing, and *Projection* printing method, respectively. [6 marks]

(b) A deep ultraviolet (DUV) excimer laser system uses an exposure light source with a wavelength of 248 nm. The nominal photoresist thickness achieved with the spin coater is 1 μm and assuming a photoresist constant of 0.75, determine the minimum feature size, W_{min}, that can be achieved using a hard contact printing, and a proximity printing method with an air gap of 40 μm, respectively. [4 marks]

(c) Design an etching process in microelectronic fabrication that minimizes the over-etch and undercutting issues in the patterning process. [6 marks]

(d) Design a fabrication processing flow for the aluminum (Al) pattern depicted in Figure 2 (d) below, using the lift-off method. [6 marks]

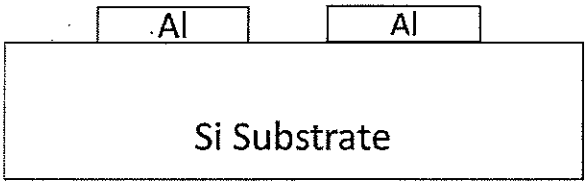

Figure 2 (d): Al patterns on Si substrate.

(e) Figure 2 (e) shows the schematic cross-section of a Si substrate with patterned metal structures. Design an etch-back fabrication process to realize the structures in Figure 2 (e). Your design should start from the Si substrate. Label each fabrication step in your design. How many optical masks are required in the fabrication design. [7+1 marks]

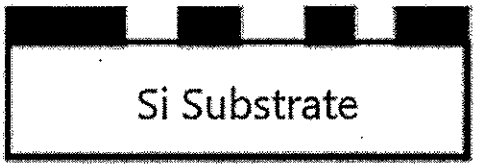

Figure 2 (e): Silicon substrates with metal structures.

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Question 3

(a) Table 3(a) summarizes the process characteristics of respective doping techniques, which include the diffusion and ion implantation techniques. Identify the types of the doping technique for the process characteristics identified in Table 3(a).

[6 marks]

Table 3(a): Process characteristics of doping techniques.

Process Characteristics	Thermal Diffusion or Ion Implantation
Low Temperature Process	
More Expensive Equipment	
Isotopic Diffusion Profile	
Amount of Dopant Can Be Controlled	
Chemical Process	
High Temperature Crystal Damage	

(b) Figure 3(b) depicts a cross-section of a silicon (Si) p-n junction diode fabricated using a thermal diffusion process. The doping concentration for the n-type Si substrate is given as $10^{15}cm^{-3}$. In order to form the p-well, the boron (B) dopants are doped into the Si substrate using the drive-in diffusion process at a temperature of 950 °C for 45 minutes. The B dopant concentration at the surface of the Si substrate at the end of the doping process is given as $10^{18}cm^{-3}$. The diffusivity of B dopants in the Si is $1 \times 10^{-15}cm^2s^{-1}$ at 950 °C. Determine the dose of the B atoms for the drive-in diffusion process, in cm^{-2}, and calculate the junction depth.

[4 marks]

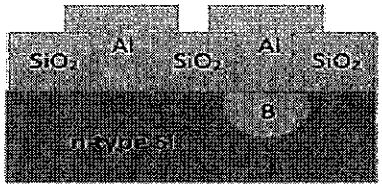

Figure 3(b): Cross-section of a Si p-n junction diode.

(c) In the design of the Si p-n junction diode given in Figure 3(b), imagine a 25 keV ion implantation is deployed to form the p-well of the Si diode. The projected range of the implanted profile is 860 Å. Given the standard deviation of the projected range as 150 Å. Determine the depth of peak of the implanted region and the peak concentration for an implantation dose of 10^{16} cm^{-2}. [3 marks]

(d) Design a deposition scheme for the aluminum metal electrode depicted in the Si p-n junction diode in Figure 3(b). Describe the deposition mechanisms of the scheme proposed in your design. [7 marks]

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Question 4

(a) Integrated circuit (IC) packaging is an integral part of semiconductor manufacturing, providing protective benefits, heat regulation, and mounting facility on electronic board. Describe the main steps involved in the IC packaging after the semiconductor front-end processes. [8 marks]

(b) Evaluate the following process characteristics of the thermocompression and ultrasonic wire bonding technologies for IC packaging. [8 marks]

Table 4(b): Process characteristics of wire bonding technologies.

Process characteristics	**Thermocompression**	**Ultrasonic**
Bonding Force		
Temperature		
Bonding Time		
Wire Material		

(c) Evaluate the potentials of the plastic encapsulated components, conventional ceramic and metal electronic IC packages in following application scenarios based on their unique material characteristics.

(i) Non-military applications,
(ii) Hermatical sealed packages,
(iii) Affordable packages with high volume manufacturing capability,
(iv) Reliable packages for harsh environment,
(v) Packages with electrical insulating features,
(vi) Packages requires thermal conductivity,
(vii) Packages requires high temperature stability,
(viii) Packages require good planarity. [8 marks]

(d) A semiconductor foundry has expanded its production capacity to 500 mm wafer fabrication. Based on the wafer tests and dice tests, the 500 mm wafer has a defect density of 10 defects/cm^2. Each die on the wafer has a size of 6 × 6 mm^2. Assuming uniform defect density, determine the minimum market price for each die if the cost for testing and packaging each die is RM 1, while the total fabrication cost is RM 1200. Evaluate the profit margin if the targeted selling price for each die is RM 5. [6 marks]

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APPENDIX

Physical Constants:

Avogadro number, $N_{avo} = 6.02217\times10^{23}$ mol^{-1}
Boltzmann constant, $k = 1.380622\times10^{-23}$ J K^{-1} = 8.61712×10^{-5} eV K^{-1}
Electronic charge, $e = 1.60219\times10^{-19}$ C
Electron rest mass, $m_o = 9.10956\times10^{-31}$ kg
Electron volt, 1 eV = 1.60219×10^{-19} J
Si yield strength = 2×10^{7} dynes cm = 7 GPa
Latent heat of fusion for Si, L = 340 cal g^{-1}
Thermal conductivity of Si, k = 0.21 W cm^{-1} °C^{-1}
Amount of heat of 1 calorie = 4.14 J
Density of bulk Si = 2.33 g cm^{-3}
Density of molten Si = 2.53 g cm^{-3}
Electric current of 1 A = 1 Cs^{-1}
Atomic mass unit of 1 amu = 1.66053×10^{-27} kg
Magnetic flux density of 1 T = 1 Wb m^{-2} = 10^4 G
Angstrom unit of 1 Å = 1×10^{-10} m = 0.1 nm = 1×10^{-4} μm
Permittivity of free space = 8.85×10^{-14} F cm^{-1}
Pressure of 1 Torr = 133.32237 Pa

Formulas:

$C = kC_O(1-x)^{k-1}$	$C_S = \dfrac{Q_T}{\sqrt{\pi Dt}}$
$\boldsymbol{\sigma = pq\mu}$, $\rho = R_s \times t$,	$N(x) = \dfrac{Q_O}{\sqrt{2\pi}\Delta R_P} e^{\left[\frac{-1}{2}\left(\frac{x-R_P}{\Delta R_P}\right)^2\right]}$
$\boldsymbol{W_{min} = \sqrt{k\lambda g}}$ $W_{min}=K\{\lambda/NA\}$	$N(Rp) = \dfrac{Q_O}{\sqrt{2\pi}\Delta R_P}$
$C(x,t) = C_S\, erfc\left[\dfrac{x}{2\sqrt{Dt}}\right]$	$Y = \left[\dfrac{1-e^{-D_O A}}{D_O A}\right]^2$
$Q = 2C_S\sqrt{\dfrac{Dt}{\pi}}$	$Y = \left[\dfrac{1-e^{-2D_O A}}{2D_O A}\right]$
$C(x,t) = \dfrac{Q_T}{\sqrt{\pi Dt}} e^{-\frac{x^2}{4Dt}}$	$N = \dfrac{\pi(r-S)^2}{S^2}$
$RC = \dfrac{R_s L^2 \in_{gd}}{d_{gd}} = \dfrac{\rho}{d_{poly-si}} \dfrac{L^2 \in_{gd}}{d_{gd}}$	$Y = e^{-D_O A}$
$x_j = 2\sqrt{Dt\, \ln(N_0/N_B)}$	$x_j = 2\sqrt{Dt}\, erfc^{-1}(N_B/N_0)$

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Values of the error function $\operatorname{erf}(t)=\frac{2}{\sqrt{\pi}}\int_0^t e^{-a^2}\,da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3491	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8472	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for $t > 3$ $\quad \operatorname{erf}(t) \approx 1-\frac{1}{\sqrt{\pi}\,t}\exp\left(-t^2\right)$

$\operatorname{erfc}(t) = 1 - \operatorname{erf}(t)$

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